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NIGHT AND SHIFT WORK OF LOCOMOTIVE ENGINEERS

2ND. REPORT. INVESTIGATIONS ON THE ORGANIZATION OF DAILY SERVICE SCHEDULES

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16. Abstract Analyzing the present regulation of work for engine drivers of the German-railroad demonstrates that discontinuity is the outstanding characteristic of their work schedule. All shifts are changed daily so that the driver is subject to an alternation in route, starting time, working time, and in the particular engine driven. For discussion of negative physiological and social effects of today's shift work we analyzed the structure of the shift. Specific time-tables of engine drivers in two German stations are discussed.

Practical suggestions are given, aimed at avoiding negative effects of work schedules that put intolerable strain on engine drivers.

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NIGHT AND SHIFT WORK OF LOCOMOTIVE ENGINEERS
2nd REPORT. INVESTIGATIONS ON THE ORGANIZATION OF DAILY SERVICE SCHEDULES

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and Joseph Rutenfranz*

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Discontinuity is the particular hallmark of the work regulations for the locomotive engineers of the German Federal Railways (DB): the work shifts follow one another in daily shift changes which means to the locomotive engineer (TF) a change in route, starting time, length of shift, and locomotive driven. The work shift changes are based on the Service Schedules. In the Service Schedules, the course of the planned service is shown, together with any deviations required by the time-table. In addition to the scheduled service, there exists a special service which includes work shifts not specified in the Service Schedules.

Inputs for the preparation of the Service Schedules for the engineer force are the locomotive route plans, the standard requirement for locomotive time in yard service, and the planned service availability of railway operating installations which

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is regulated by the railway management. In this connection, there is presented, on the one hand, a coordination problem which must be cost-effectively solved by the railway operating installations personnel utilization authority, i.e., the fixed traffic performance, yard service, and service readiness must be planned with the smallest possible commitment of personnel. On the other hand, under the Hours of Work Regulation (DDV) there intervene certain legal labor protection considerations (compare the 3rd Report— Ergonomic Analysis of the DDV of the DB).

In preparing the Service Schedule, there exists a coordination problem with recognized boundary conditions. To be sure, this problem is being solved at the moment "by hand" for the 33,958 employees of the locomotive service (DB report, yearly average for 1971), for which purpose it required 578 employees continuously, so that for each 59 employees in the locomotive service, there was at hand one position dedicated to personnel utilization.

In order to evaluate the work time regulation taken as a basis for current Service Schedule formulation from an ergonometric and labor health standpoint, we have investigated* how the Service Schedules are put together and what criteria underlie the production of a Service Schedule. Our investigations took place in three steps: First the synthesis of a work shift was analyzed, then we looked at the associated Service Schedule formulation, and finally concrete Service Schedules met within two railway operating installations were discussed and analyzed.

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* Our investigations were suggested by and generously supported by the Federal Minister for Transportation.

I. THE SYNTHESIS OF A WORK SHIFT

If one looks at it from the operational point of view, one can differentiate three model types for locomotive personnel: the local traffic, long distance traffic, and yard types. Local and long distance can be differentiated into passenger and freight traffic. For the activity of the engineer, however, the /101 traffic type alone is not adequate characterization; more important also is the traction mode — diesel, electric or steam. Table 1 presents the traction mode that is currently preferred for each operational mode, whereby further traction modes have been ignored since their current and future significance seems small. Also, the significance of steam in long distance traffic is for the most part confined to single stretches.

In analyzing the synthesis of the work shift, we found that the operational requirements affect the personnel utilization planning more strongly than does the traction mode. The work of the locomotive engineer (TF) is strongly dependent on the operational means and the time-table. This dependence is illustrated in the comparison shown in Figure 1 between service plan and course plan.

TABLE I. CLASSIFICATION OF THE WORK OF LOCOMOTIVE ENGINEERS FROM THE TECHNICAL AND OPERATIONAL STANDPOINT

Traction mode	Operational Mode				
	Local traffic		Long distance traffic		Yard service
	Passenger traffic	Freight traffic	Passenger traffic	Freight traffic	
Diesel	x	x			x
Electric	x	x	x	x	
Steam	x	x	x	x	

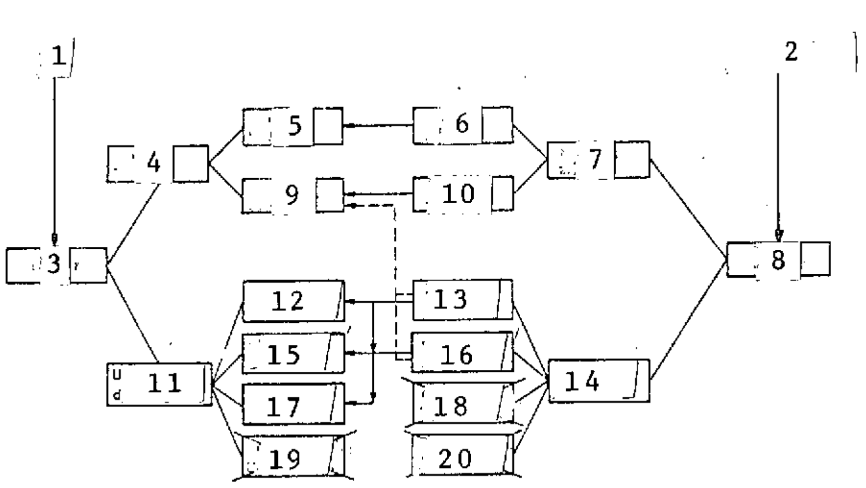

Figure 1. Explanation of the operational mode and schedule-linked activity of locomotive engineers. Comparison: Schedule of the Engineer (TF) and Course Plan of the Locomotive (TFZ).

1- service schedule; 2- course plan; 3- engineer time; 4- work time; 5- main activity; 6- main employment; 7- employment time; 8- loc. time; 9- secondary activity; 10- secondary employment; 11- interruption of activity; 12- service-caused interruption; 13- service-caused interruption; 14- interruption of employment; 15- mishap-caused interruption; 16- mishap-caused interruption; 17- rest; 18- rest caused interruption; 19- personally caused interruption; 20- personally caused interruption.

The dependence of the engineer's work on the operational mode and on the time-table is also expressed in the varied distribution of individual work activities within a given work shift. As the shifts shown in Figure 2 for local traffic, long distance traffic and yard service show, an engineer's work shift includes (in DB terminology) the following time divisions: running time (train running and stops, yard service), interruptions (operations or traffic interruptions, work breaks and standbys, or any other interruption), as well as preparatory and shut-down services (technical and operational type).

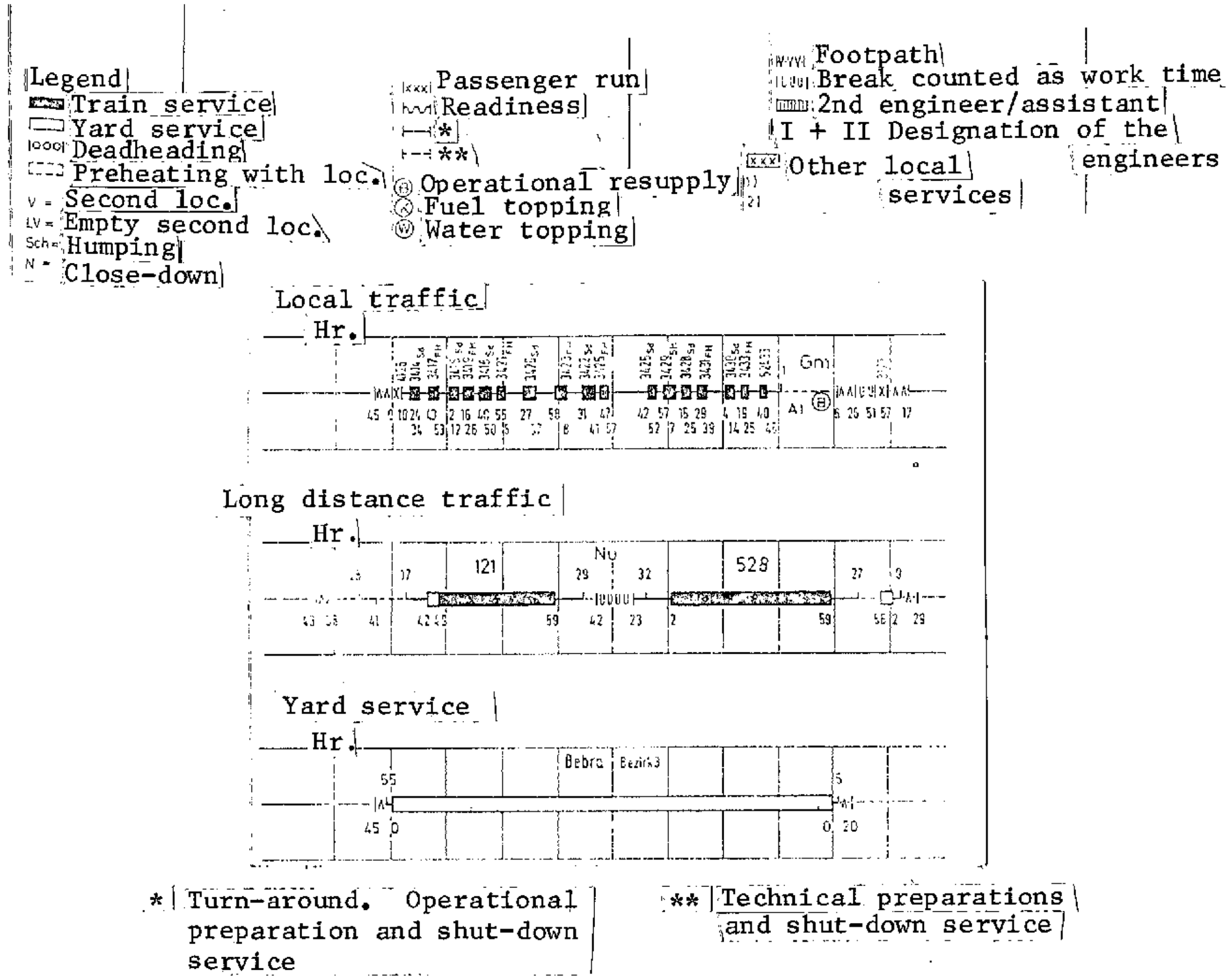

Figure 2. Structure of the three most important types of shifts. The three bar charts are photocopies of the original presentation of the time distribution of activities within a work shift for three traffic modes and for three railway operating installations.

From the three diagrams in Figure 2, one can see that at the beginning of a shift, technical and operational preparations /103 occur which in general can last from 5-60 min. The length of the running time which follows varies widely (for the railway operating installations at Frankfurt and Bebra, we have, for example, determined from the summer Service Schedules for 1971 that the duration of uninterrupted running time was between less than 1/2 hour up to 5 hours). The duration of the uninterrupted running time is also exactly the particular difference between local and long distance traffic. While in local traffic, the uninterrupted running time can be very short (ca 10 min), if

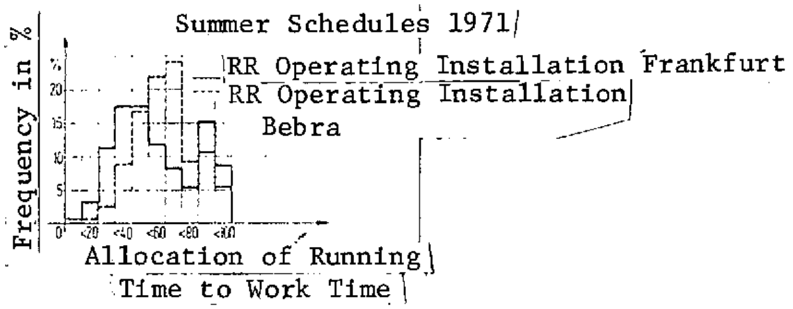

Figure 3. Frequency distribution of the allocation of running time to engineer work time.

long distance traffic running times of up to 5 hours occur. Since yard service is not tied to a time-table, very different running times occur in it.

If one compares the results for the two operating installations, Frankfurt and Bebra, one notices the dependence of work performance on the traffic situation, which in turn is a question of location. As Figure 3 shows, in the case of Bw Bebra, relatively long running times appear, which are distributed evenly over the allowable duration. Bw Frankfurt is, on the other hand, characterized by a large proportion of yard operations (running time more than 70% of the work time) as well as a higher proportion of small running times.

After a run operational and technical shut-down work must be undertaken (see Figure 2). These also — like the preparatory services — are phased and can take up about the same time as the preparatory services.

By work time is understood, the running time plus the time for preparatory and shut-down services. As Figure 1 shows, the work time is, in its structure and content, linked to the use-time of the locomotive (TFZ). Based on economic considerations and because of the dependence of the locomotive on the time-table, rest periods put into the Service Schedule as breaks, and waiting times caused by work flow or disturbance conditions always fall together. Only breaks take place which are caused by operational or traffic conditions. Interruptions of work which are personally decided by the engineer are lacking (therefore deleted in Figure 1), just as are rest or personally-condi-/ /104 tioned interruptions in the course plan of the locomotive. Waiting times which are conditioned by the progress of the work and break time in the operational means conform to each other, in relation to the particular locomotive. Otherwise there arises a work progress-conditioned waiting time because of gaps in the Service Schedule caused by the time-table. Waiting times and break times related to break-downs are incongruous if the engineer himself is required to take care of the break-down. Rest time as a time of quiet and the time when equipment is out of operation correspond with one another if the engineer is not required to change engines in those cases of externally caused standstill or pause. The three diagrams in Figure 2 show further that other pauses occur in all work shifts and with various durations. In this connection, most of the longer pauses in long distance traffic lie in the middle of the work shift because of waiting on sidings. In the case of local traffic, the time-table often requires uninterrupted work shifts.

II. SERVICE SCHEDULE FORMULATION

The work time of the DB engineer is regulated by the Service Schedule. The Hours of Work Regulation (DDV) itself only contains minimum guidance with respect to organization of the work, although it sets the limits which must be adhered to. In DV 948A, good management is called out as the leading criterion for Service Schedule formulation. Accordingly, Annex 4 of that DV provides the following guide for the drafting of Service Schedules:

1. From the locomotive (TFZ) course plans, appropriate work shifts are to be created following the DDV — the shift changing times to be as short as possible.

2. These are filled out with yard service time, times for preheating, and other local services for preparatory and shut-down tasks.

3. The sum of work times of all the work shifts represents the work time that falls to each depot on a standard schedule day. This work time sum must, however, be adjusted since on certain days Service Schedule tasks must be carried out which deviate from the standard schedule.

4. From already existing Service Schedules a factor is derived:

$$F = \frac{\text{Mandatory work time in a 7 day period x No. of TF}}{\text{Sum of the work times in the standard schedule}}$$

which factor is a measure of deviations from the standard schedule. It lies between 6 and 7.

5. The work time in a 7-day period on the average is determined:

$$AZ_{A7} = \text{sum of the work time in the standard schedule x F}$$

6. The number of required locomotive engineers (TF) to carry out this amount of work results from:

$$\text{Number}_{TF} = \frac{AZ_{A7}}{42}$$

The number 42 is the mandatory work time in the average 7-day period.

Considering now the locomotive model types and the rating of the positions, the engineers are organized into groups. In this way the so-called "Usage" is developed, the /105
grouping together of 12 engineers for 12 days in order to attain the work distribution shown in Figure 4 while at the same time holding a near-constant interval between days-off (R).

7. This selected number of Service Schedule days (number of engineers) is filled up with the work shifts that have been created, paying attention to the prescribed number of days off, to the minimum duration of days off and breaks, as well as attention to the job rating. The pay levels specified in the Service Schedules must match the individual pay grade groups of the engineers. As far as possible, the shifts should be put together in the Service Schedules in such a way that a suitable value is attained. In addition to the type of train, the travel time in the locomotive is the basis of this evaluation process. Service Schedules with high value are produced either with high-valued types of trains on short journeys or with lower valued train types with long travel times. In practice, Service Schedules must often be put together with a mixture of jobs.

8. These shifts which appear in the Service Schedules must be so arranged that strenuous jobs and night shifts are distributed and breaks take place insofar as possible in the home location.

At this point, the sequence of shifts is promulgated as a standard format without prior express notice. The result of this sequence is a Service Schedule that extends over as many weeks as the days included in the Service Schedule.

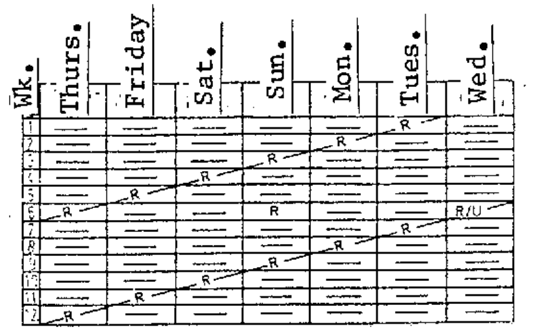

Figure 4. Usual pattern for ordering of the work distribution. R- day off; R/U- day off with training; excess days off are concentrated on Sunday.

9. Deviations which were determined in the process up until now, are included in the weekly plans which serve as a basis for no comparable periodicity.

If one represents these planning steps in a flow diagram, then the flow is as shown in Figure 5. Since the boundary conditions applying to the difficult problem of coordination in putting together the Service Schedule are well known, and all the individual elements of the flow are quantitatively understood, the employment of operations research procedures using electronic data processing facilities would suggest itself. Even though exact solutions appear difficult, if not completely impossible, due to the complexity of the problem, nevertheless heuristic processes certainly are available, which with a minimum time requirement develop several alternate solutions, which then need to be evaluated. One such heuristic procedure could consist in the theoretical application of the process which is now carried out exclusively manual. The use of an electronic data processing facility would increase the speed of planning and make possible the creation of many alternative solutions. The alternatives presented can straight away be used as a basis for the ergonomic and occupational medical evaluation of the Service Schedules; in this way the possibility is basically increased to discover an

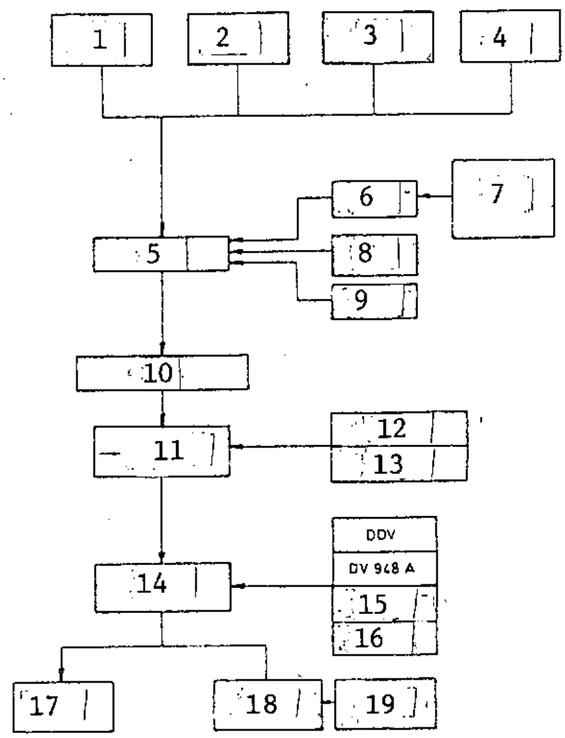

Figure 5. Service Schedule formulation in the DB.

1- locomotive course plan; 2- yard service; 3- preparatory and shut-down services required by regulations; 4- other services; 5- work shifts; 6- cost effectiveness; 7- short breaks and shift change times, no deadheading, long running times; 8- hours of work regulation DDV; 9- job rating; 10- Σ DF, F, AZ_{A7}, no. of engineers; 11- Formation of groups and schedule periods; 12- locomotive model; 13- job rating; 14- filling out of the days with shifts; 15- job rating; 16- advice of the personnel counselor; 17- serial schedules; 18- weekly schedules; 19- distribution of remaining jobs;

optimal solution which goes beyond the mere adherence to a criterion of cost effectiveness.

III. ANALYSIS OF ACTUAL SERVICE SCHEDULES

After the formulation of the Service Schedule was studied and described, we undertook to analyze and discuss actual Service

Schedules. A Service Schedule for an engineer consists of three parts: the indicator section, the weekly distribution in the schedule, and the computation section. In the indicator section there are shown the different jobs which pertain to the individual standard schedule days, together with their times. In addition, deviations from the standard schedule are shown. Deviations ensue if any day of the week — in particular Saturday or Sunday — requires a job performance which is required by operational considerations to be different than on the other week days. In the weekly distribution section, the work shifts falling on the individual days of the week are shown in their time spots. The computation section serves as a computational basis for the determination of work times and gives the length of the individual work packages in a work shift.

The Service Schedules are periodically carried out by the engineers — that is, Engineer N begins on service day N. Since the number of service days is a whole number multiple of 7 only in the rarest cases — normal day-off planning must avoid this — the new cycle begins for the individual engineer always on a different day of the week. Only after running through the number of weeks which corresponds to the number of standard days, does he start through the same cycle.

1. The Research Material

The analysis of actual Service Schedules was carried out for the scheduled service on the summer schedules of the railway operating installation (Bw) Frankfurt in 1971, and for the special service on the performance reports of the Bw Darmstadt for October 1971. The inquiry into special service performance at Bw Darmstadt proved to be very time-consuming so that only a 15% sample could be evaluated. A comparison with other special services shows, however, that this sample was representative.

Likewise the Service Schedules of Bw Frankfurt can, despite the difference in individual Bw's, be considered as representative.

2. Questions Posed for the Service Schedule Analysis

The following features of the Service Schedules were investigated and their differences in the case of the regular and special service were established:

(1) Number of consecutive night shifts. Shifts that were for the most part in the time from 11:00 p.m. - 5:00 a.m. were counted as night shifts.

(2) The number of rest breaks away from home whose beginning or end is between midnight and 4:00 a.m.
(The effectiveness of relaxation of these breaks seems limited based on the possibility for rest accommodations and the shortness of the break time.)

(3) Number of work free nights between two consecutive night shifts.

(4) Length of the day off.

(5) Interval between days off

(6) Distribution of the days off over the days of the week.

(7) Length of the break times.

3. Results of the Service Schedule Analysis of the Scheduled and Special Services

In the scheduled service, a total of 2,520 work shifts (man days) fell in the 12 weeks which we investigated. In these, 25% of the nights were occupied with work and/or with breaks away from home, in which connection the major part of /109 the night shifts occurred as double or multiple night shifts (see Table 2).

TABLE II. SEQUENCE OF NIGHTSHIFTS

	Frequency in percentage (%) of n-fold nightshift				
	Single night-shift	2-fold night-shift	3-fold night-shift	4-fold night-shift	5-fold night-shift
Scheduled Service (BW Frankfurt Summer 1971)	17	40	40.5	2	0.5
Special Service (Bw Darmstadt Summer 1971)	37	30	25	7.5	0.5

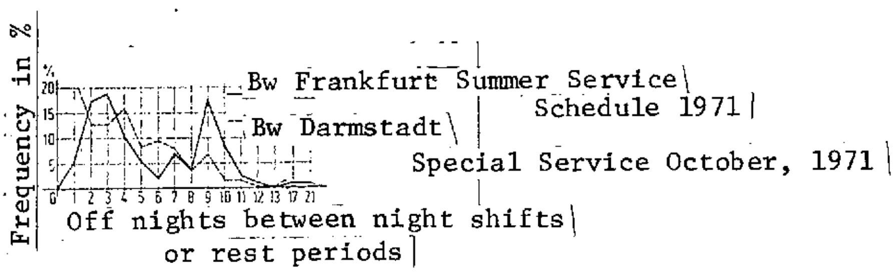

Figure 6. Distribution of Night Shifts

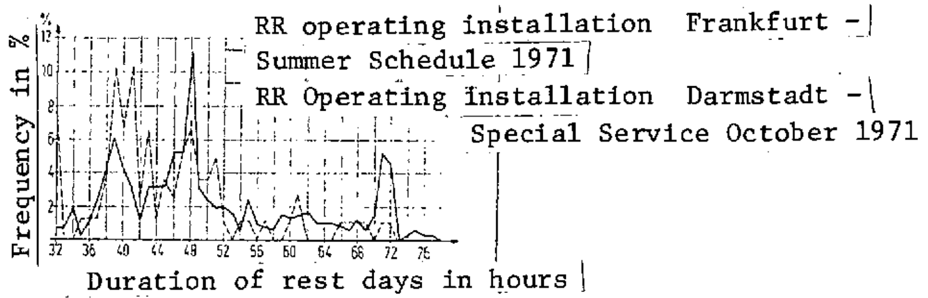

Figure 7. Distribution of the duration of days off.

TABLE III. INTERVAL OF DAYS OFF (FREQUENCY IN PERCENT - %)

	Work days between 2 days off									
	1	2	3	4	5	6	7	8	9	10
Scheduled Service (BW Frankfurt, Summer 1971)	7	16	9	17	45	4	1	0.5	0.5	-
Special Service (Bw Darmstadt, October 1971)	8	11	8	14	22	14	8	4	7	4

TABLE IV. DISTRIBUTION OF DAYS OFF AMONG THE DAYS OF THE WEEK Bw FRANKFURT: SUMMER SCHEDULE 1971; Bw DARMSTADT: SPECIAL SERVICE OCTOBER 1971*

	RR Operating installation (Bw)	Days of the week off						
		Wed.	Thurs.	Fri.	Sat.	Sun.	Mon.	Tues.
Frequency in [%]								
Days off	Ffm	11,5	11	11,5	6	11,5	10	10,5
	Da	7,5	6,5	14	13	19	5,5	8,5
Weekend off (free Sat. and Sun)	Ffm	—	—	—	7,5	7,5	—	—
	Da	—	—	—	4	4	—	—
Long weekend off (free 1/2 Fri+Sat+Sun+ 1/2 Mon.)	Ffm	—	—	2,5	5	5	2,5	—
	Da	—	—	3	6	6	3	—
Total days off	Ffm	22,5	11	14	18,5	24	12,5	10,5
	Da	7,5	6,5	17	23	29	8,5	8,5

* Translator's note: Commas in numbers represent decimal points.

The free nights between night shifts, or breaks away from home, are distributed as shown in Figure 6 (traced curve). One can recognize the intention, at least in some Service Schedules, to have a large number of free nights follow a continuous number of night shifts. However, in connection with the rests away from home, we were not able to determine this intention: in 41 cases nighttime away from home breaks either preceded or followed a night shift. In two cases away from home breaks at night were linked with two night shifts, and in one case two breaks away from home followed on each other.

Figure 7 and Tables 3 and 4 show the length, the intervals and the distribution of the days off. In the case of the length distribution of the days off, three significant peaks show up (Figure 7, traced curve). In the case of the interval of days off (Table 3, the striking maximum shows the dependence on the Service Schedule formulation in use (compare Figure 4). This applies also to the distribution of the days off among the days of the week which are shown in Table 4. There are a plethora of days off on the weekends. Altogether there is a day off about each 5 days (Table 3). In the case of the rest periods, one can determine a similar distribution in duration. A difference between rest times that follow day shifts and those that follow upon night shifts could not be determined.

The <u>special service</u> showed marked differences from the /110
Scheduled Service in those criteria that were investigated by us. In the time period which we examined of four weeks, 465 work shifts (man days) occurred. In fact, the portion of the work shifts involving night work was also at 25% in the case of the special service, although in this case a larger part of the night work was performed in individual night shifts (see Table 2). With this distribution of night work, the number of free nights

between the night shifts becomes smaller (Figure 6).

The most significant difference from the scheduled service can be determined in the length (Figure 7) and the interval (Table 3) of the days off. In general, one can determine a shift towards shorter duration, and particularly also the frequent occurrence of the minimum rest period (within the meaning of the DDV specified 32 hrs). Longer days off, as in the scheduled service, occurred only separately. This abbreviation in the duration of the day off finds its correspondence in the longer rest period compared to the scheduled service. Here one can clearly recognize the lack of the possibility of choice which inheres in the special service regulations. This also requires, to be sure, the frequent granting of minimum rest periods, so that for all the rest periods one sees a distribution with peaks at both extremes.

The even-handed distribution of days off is no longer found in the case of the special services. Here one also finds an average of a day off every five days, but the distribution stretches over larger values (Table 3). The distribution over the days of the week (Table 4) shows the same values as in the case of the scheduled service.

In summary, the analyses of actual Service Schedules in scheduled service as well as in the special service show that in many cases the schedules have exceeded (and by no small amounts) the basic maximum work shift duration of 10 hours, the minimum rest time between work shifts of 12 hours specified in the regulation, and finally the minimum duration of the day off of 32 hours.

IV. DISCUSSION OF POSSIBLE NEGATIVE EFFECTS OF CURRENT SERVICE SCHEDULE FORMULATION

It was determined that the hallmark of the Service Schedules of engineers is discontinuity. Only the constant day off interval of 5 days (see Table 3) appears as a stabilizing factor. The central problem of Service Schedule formulation consists in the temporal coordination of engineers and jobs under varying boundary conditions. If one considers the work shifts in the formulation of the Service Schedule as a fixed value, then the coordination problem consists in the distribution of the daily-occurring work shifts among the various engineers. In contrast to the constant activity flow in industrial installations, homogeneous work requirements which could be easily assigned to the work force do not fall over the whole day; in fact, particular work shifts do not fall on particular times of the day. In the case of the DB, the work shifts (n) that fall on a day are selectively assigned to the engineers; in industrial plants, on the other hand, tasks $n_{1,2,3}$ are linked to the workers $n_{1,2,3}$. The difference in work schedules arising from this is schematically shown in Figure 8.

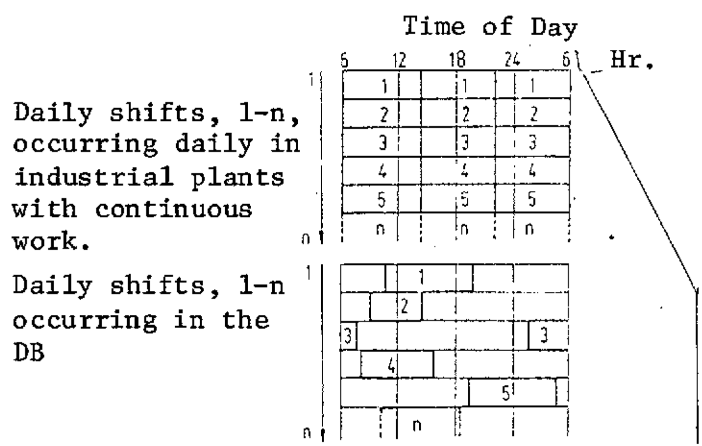

Figure 8. Work schedules in an industrial plant (above) and in the DB (below).

Possible negative effects of the current Service Schedule formulation in the DB are principally to be seen in the psychological and social sectors. Since the biological diurnal cycle is the principal factor in both strain and recovery, and therefore in the performance capability of the work force as well as the safety of the plant, (see Hildebrant, et al., in press) it seems together basically fraught with problems to set up work shifts based purely on the time duration of the required service, and thereby to ignore the absolute time of day, i.e., the realities of the diurnal cycle, with a few exceptions as, for example, in the case of the definition of the night shift. An important goal for the further development of the Service Schedule formulation for shift workers of the DB would be the changing of the regulations into a work time arrangement in which the modifying influence of the biological diurnal cycle is properly taken into account (see also Hildebrandt, et al., 1973, 1974).

In addition to possible damage to health and physical complaints which can arise as a result of current Service Schedule formulation for engineers, problems based on current DB Service Schedules which affect the off-duty social sphere seem also unavoidable. Each society exhibits certain typical rules for the social life of its members which can be historically conditioned and variable. This is particularly true in the case of the time circumstances for work and free time. Every performance of a social role outside the normal time must be perceived as abnormal and isolated.

Under the prevailing social time organization, certain shift arrangements must be viewed as unfavorable. In this connection, the DB should again make clear whether these unfavorable effects can be minimized by a <u>shift sequence of identical shifts</u>. The shift arrangements can be called favorable when they guarantee the most time possible for homogeneous activities in the social community, e.g., with the family.

Because of the constant changing of the time arrangements of the shifts, the DB engineer loses the synchronization of his work free time, mealtime and sleep rhythms in his social environment, and the periodicity of his schedule which is not linked to the week gives rise to an insufficient predictability of his free days (for it is said that the engineer always has his schedule either in his head or in his pocket). As a result the engineer is forced into social isolation. His family environment cannot compensate for this since one cannot expect a daily reorganization of the family to fit the father's shift changes. Free time and meals together in the family seem difficult, particularly when one considers the unfavorable holiday and Sunday rules.

So these social aspects also call out for a change in the formulation of Service Schedules, which above all, would serve to bring a greater continuity of family life, free time, and relationship to the social group. Furthermore, since sleep interruptions must not only be avoided basically because of their negative effect on the work shift, but are also to be considered an important source of health problems (and this health danger must be particularly taken into account precisely because of the discontinuity in schedules of the DB in contrast to other business and industrial shift schemes), practical measures should be taken which result in an improvement in the current Service Schedule formulation in the DB.

V. PRACTICAL CONCLUSIONS

In consideration of a more even life rhythm and in order to develop more stable free-time habits, shifts in the same period and of the same length, or the same shifts (night shifts aside) must follow one another. All work shifts (n) constituted in conformity with Service Schedule formulation would thus be put together /113 in packages all having the same time location. If one allows a variation of 1-2 hours, one can put together work shift packages n_1, n_2, n_3 whose beginning times match the usual shift change times one finds in industry. This measure can be supported by an appropriate modification of the work shift structure. This first step can also be carried out under normal current Service Schedule formulation, especially since there already exist today particular points of time which are emphasized in setting up the beginning times for shifts. With respect to the objectives mentioned above, this would lead to a wide improvement: one would attain a more even distribution of the shifts in time, linked with more even rest periods and longer days off.

In connection with these considerations, further questions play a central role — how many night shifts can follow one on another from the ergonomic and occupational medical viewpoint? — and what rest times should be assigned following a night shift? (see Rutenfranz, et al., 1974). For those DB routes demanding a high operational safety the avoidance of the cumulative effect of a sleep deficit seems absolutely required. In addition, one should limit as far as possible the additional strain caused by the violation of the biological diurnal rhythm, whose "internal clock" has not been reset even in the case of locomotive engineers.

Rutenfranz (1971), in agreement with the research results reported here, reported on the possibility of an accumulation of sleep deficit and on the fact that problems caused by either total or partial withdrawal of sleep can be overcome by a single normal sleep period. Considering this aspect, each night shift should be followed by a rest period of at least 24 hours. (Principle of nightshift distribution). Thereby a shorter day-time and a normal nighttime sleep period becomes possible. Only in this way can the sleep interruptions, within the meaning of the work protection law, be combatted.

If one supplements the proposals made above with two further measures which appear significant in this connection, the following list is produced:

1. Shifts which are similar in length or identical should be incorporated in one shift sequence.

2. Night shifts should be treated according to the principle of night shift distribution.

3. Following each night shift there should be at least a 24-hour rest period which does not count as a day off.

4. Every third weekend should be a long weekend and every other Sunday should be a day off.

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